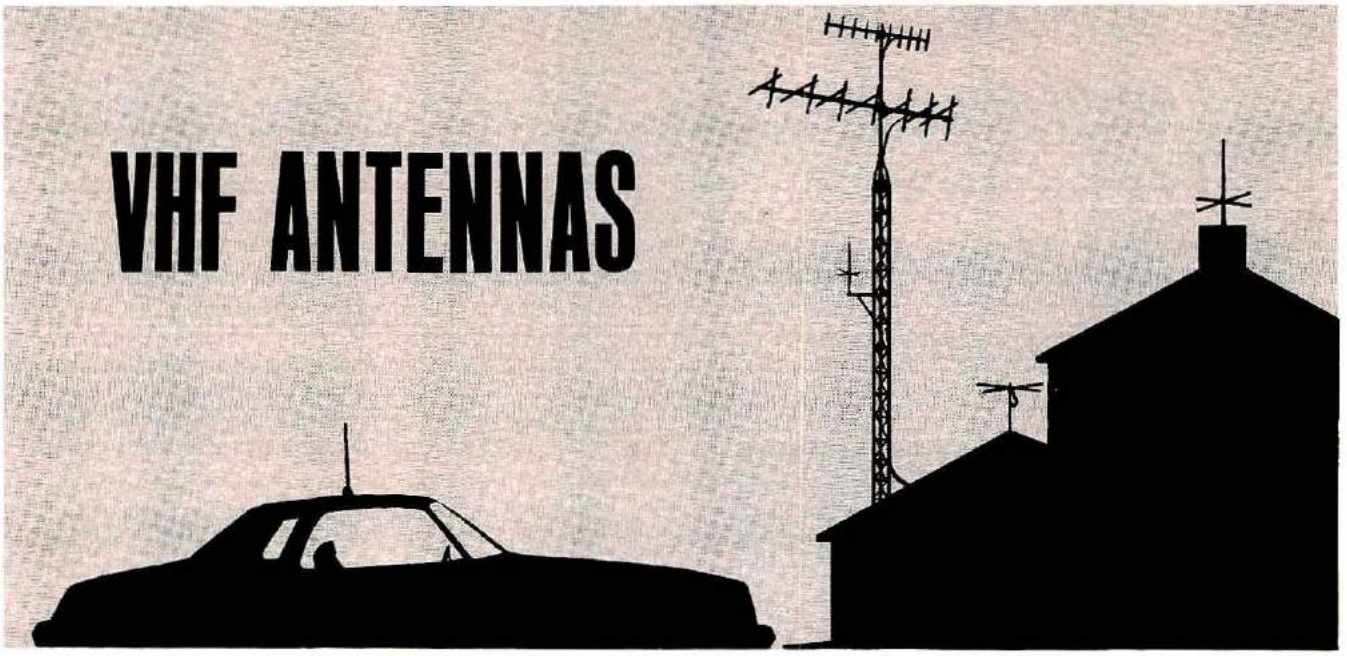


# VHF ANTENNAS

BY THOMAS McMULLEN, W1SL

## A look at some antennas you can use for most common modes of vhf operation

What kind of antenna do I need to talk through the Oscar satellite? What antenna works best for mobile fm? Umm . . . why do you ask — what do you have in mind? Oh, yes, now I get the picture — you are ready to go for your General or Technician exam, and you're planning ahead for a type of operating that you've never done before. Great! Good thinking.

Well, I could duck out of that question by saying that you can probably get by with what you have been using, but then you would try it and find that your 80-meter inverted-V just wasn't very good at 145 MHz. Oh, yes, it would work to a degree — sometimes.

Vhf antennas are a little bit different, but not enough so to upset any theory you have already learned. The biggest thing to keep in mind is that the losses in the whole system are greater than they were at 80 or 40 meters. And that means the *whole* system; feedline, antenna elements, and the path through the atmosphere. You can take care of the feedline problem by either keeping it as short as possible, or by using the best cable you can afford. Antenna elements should be made of low-loss metal, but unfortunately gold is just slightly more expensive than steak, so we will have to settle for aluminum, and try to keep it free of corrosion by protecting it with a spray-on coating. Yes, copper would be better, but it is heavier and still needs to be protected.

### Talking through Oscar

Enough of this discussion of materials; let's look at some other important requirements, like the radiation pattern for instance. Sure, you need to know about that! Otherwise you could waste a lot of time trying to talk through the satellite when your signal was not even getting there. Take a look at **Fig. 1**. Some radiation patterns are shown there, one for a dipole that is one-quarter wavelength above a conducting screen, another for a spacing of three-eighths wavelength. I have also shown the pattern for a medium-sized beam antenna.

When the satellite comes over your horizon, at position A, you can see that it is not yet in the main part of your antenna pattern, so results would be poor. Yeah . . . the beam antenna would take care of that, but it has other problems which I'll get to in a minute. As the satellite gets closer, it starts to enter the pattern from your antenna and it becomes easier to "access" the bird, as the saying goes. That is why the dipole with a spacing of 3/8 wavelength is recommended — it has a useful response area that starts approximately 20 degrees above the horizon. Don't let that little dip between the 50-degree points bother you; by then the satellite is closer to you (at position **B**) and not as much gain (or power) is needed. The pattern for the dipole with 1/4-wavelength spacing is useful for overhead work, but is so poor toward the horizon that I wouldn't consider it. I put it in there just to show what the "incorrect" spacing can do for you. No . . . making the spacing greater than 3/8 wavelength is no good either because the pattern keeps getting a bigger dip in the middle, and finally breaks up into several pieces with even bigger holes in it.

So there you have a pattern

that is generally useful, and you can stick the antenna up on a TV mast or chimney, or even just perch it on a porch rail if you like. Of course the pattern shown was for a single dipole, and the discussion assumes a directly overhead pass of the satellite. However, you can spread the pattern out a bit and do a good job when the satellite is off to one side of you just by putting up another dipole that is at right angles to the first. This is called a turnstile antenna, **Fig. 2.** The turnstile can be mounted above a ground screen very easily (**Fig. 3**). Why do you need the screen? Well . . . it's like this: The screen establishes a definite "reflective" surface under the dipole so that the pattern can be formed by the process of reinforcement. You know — that's like when you put a mirror beside a light bulb. The light rays that would have gone off to the side are now reflected toward you, the light then seems brighter. If there were no conductive surface under the antenna, the pattern would be unpredictable. Another function of the screen is to "shield" the coaxial cable from the antenna and, at the same time, shield the antenna from noisy electrical things below it.

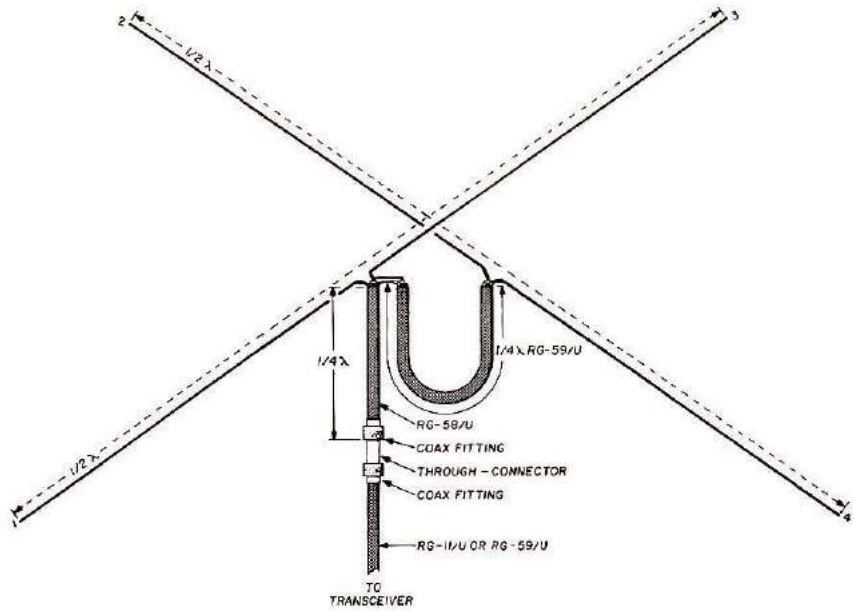


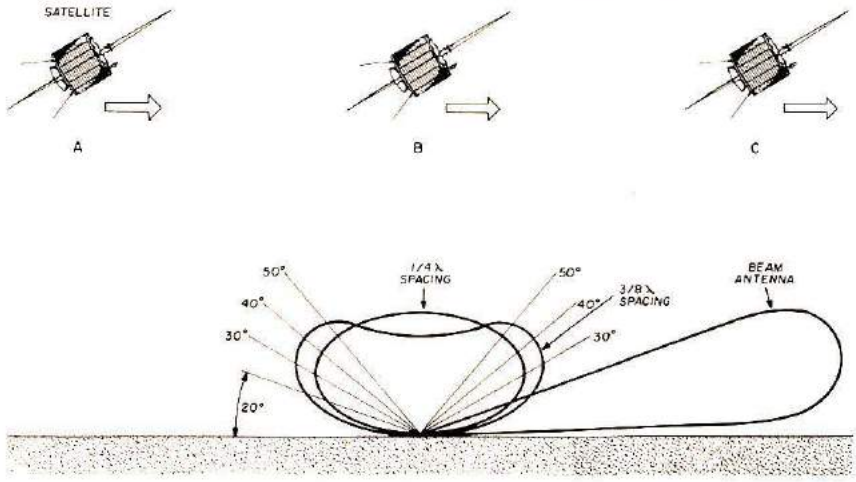

**Fig. 2.** A turnstile antenna can be made from pieces of brass or copper-clad welding rod for the elements, and coaxial cable for the feedline and phasing loop. When you cut the 1/4-wave sections of cable be sure to allow for the propagation (velocity) factor of the coax you are using. For most common cable, RG-8/U, RG-11/U, RG-58/U, or RG-59/U, it is approximately 0.66. For example, from **Table 1**, 1/4-wave at 146 MHz is 20.2 inches (51.3cm). Multiply this by 0.66 to obtain 13.3 inches (33.9cm), which is the length you should have between the ends of the braid for the pieces of RG-58 and RG-59.

### Beam antennas

Okay — let's take a look at what a beam antenna will do for you. As you can see from the radiation pattern, it is a mighty handy thing if you want to catch the satellite at the horizon, and the gain will allow you to use lower power and still talk through Oscar. Sounds great, right? As always, there's a catch. With the antenna pattern only 30 degrees wide, and the satellite moving at a rate of approximately 2.3 degrees per minute, how long is it going to stay in front of your antenna? Right! Thirteen minutes. That means that you'll have to move the beam to keep up with the bird, and you'll have to plot the path pretty well so you know which direction to point the thing.* It could be east of you, west of you, overhead, north, all sorts of combinations are possible, both in height above the horizon (elevation) and direction around the compass (azimuth).

There's nothing wrong with having to move the antenna to chase the satellite — in fact you'll eventually probably want to do just that. However, I would recommend starting with a simple arrangement so you

**Fig. 1.** Radiation patterns (or signal pick-up area) for horizontal antennas above a ground plane or conducting screen. Two very useful patterns are those of an antenna at 1/4-wavelength and at 3/8-wavelength spacing. Increasing the spacing causes the pattern to break into segments with notches that would cause the signal to disappear. A pattern that might be expected from a modest-sized beam antenna is also shown for comparison. The Greek letter Lambda (λ) is a symbol for wavelength.




*An Oscar-locating aid, called the Satellabe, can be obtained from *ham radio's* Communications Bookstore for $7.95. See page 23 of the March, 1977, issue of *Ham Radio Horizons* for a photograph.

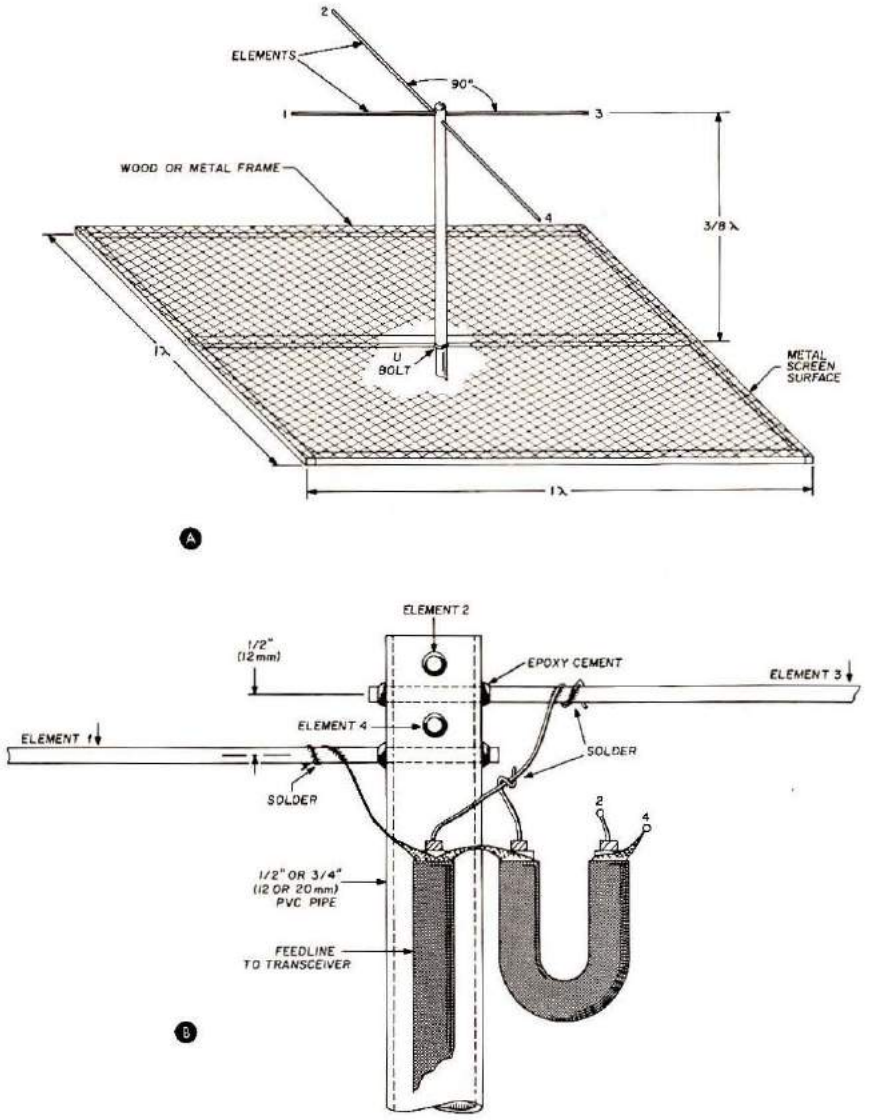



**Fig. 3.** The performance of a turnstile can be improved by mounting it above a ground screen. The screen can be coarse mesh, such as chicken wire, or fine mesh such as that used for windows. It must be of metal — plastic will not work. An enlarged view of the connections and method of mounting the elements is shown at **B**. After all the connections have been made at the end of the coax and the elements, they should be protected with vinyl electrical tape and clear spray coating, or by sealing with GE RTV Silicone sealant. The coaxial cable can be taped to the vertical support to prevent placing stress on the connections. A small hole in the screen to allow the support and the coaxial cable to pass through will do no harm.

can devote plenty of time to operating and get the hang of it. After you have your timing and procedure all smoothed out, then you can start thinking about a beam to reach really out to the horizon and work the more distant stations.

Beam antennas come in varied sizes and shapes and with gain figures that range from just a couple of dB up to 18 or 20 or more, depending upon how hard you are willing to work at it. The penalty that you pay for higher gain is that the radiation pattern is narrower, and it does not take too long to reach the point where it is so narrow that you cannot keep the antenna pointed at the satellite. A good compromise is an antenna with a gain of approximately 10 dB. It is large enough to make up for some transmission-line loss and allow the use of comparatively low power, but at the same time it is physically easy to handle and install. **Figs. 4** and **5** show an example of what might be typical construction for this type of Yagi antenna. It can be made from parts of an old TV antenna, or from aluminum tubing or wire that can be obtained at your local hardware store.

There are many ways to mount an antenna of this type, and I could not begin to talk about all of them here. A garden-variety TV rotator will handle it with ease, and if you fasten it to the vertical support so that it faces upward at approximately 30 degrees, it will cover the majority of satellite passes for you (**Fig. 6**). If you really want to go all the way, you can use two rotators, one to rotate the antenna horizontally, the other to tip it from the horizon to straight up. Of course, this more flexible system will require two rotator controls, and at least two hands to keep it going in the shack, so better count the number of hands you have before installing such a system.

No, I haven't forgotten your nice new mobile fm rig. I was just about to get to them. Right now it is a toss-up as to just where the most activity is — satellites or repeaters. They are both wonderful areas to explore, so let me tell you about a few antennas you can think over for fm use.

### FM antennas

Very simple antennas can be used with your mobile or portable fm transceiver, and a very common type usually turns out to be a 1/4-wave whip. It can be mounted on a car-top or trunk lid, and is often seen sticking out of the top of the various portable units, both hand-held and shoulder-strap types. As a quick and easy antenna to make, it is hard to beat. It will work with common 50-ohm transmission line without a need for a matching transformer; it can be made

from almost any chunk of wire that is of the right length; and the radiation pattern is not all that bad (see **Fig. 7A**).

Ideally, this type of radiator should have a ground-plane to help it, for the same reasons that one was so helpful to the dipoles and the turnstile I just told you about. In fact, a quarter-wave vertical radiator, with either radial rods or a screen located at its base, is called a *ground plane antenna*.

There is one minor hitch, however: In amateur work most antennas have gain figures that are referenced to a half-wave dipole. Since the 1/4-wave antenna is smaller than a 1/2-wave one, then it follows that the gain will be less for the smaller antenna. This is an important point to remember when you look at all the gain-claim figures in the advertisements — no one has yet found a way to put 5 pounds of gain in a 1-pound bag! Always try to find out what the reference is when comparing performance claims.

Yes, half-wave antennas can be used above a ground plane too, with the application of a little trickery to keep the coaxial cable happy. Y'see, the impedance at the end of a half-wave radiator is very high, thousands of ohms,* and if you just connected it directly to the end of a piece of 50- or 75-ohm coax, most of your signal would spend its life bouncing back and forth along the cable, looking for a way out. So you have to place a matching network at the end of the antenna, between it and the coax. The term "matching network" is just engineer-type talk for a circuit that acts as a transformer — it helps two widely different impedances get along together. In the case of our half-wave antenna and coax, it can be just an ordinary coil made up of the appropriate number of turns of wire, or it can be a tuned circuit with both the coax and the antenna attached at the proper points (**Fig. 8**).

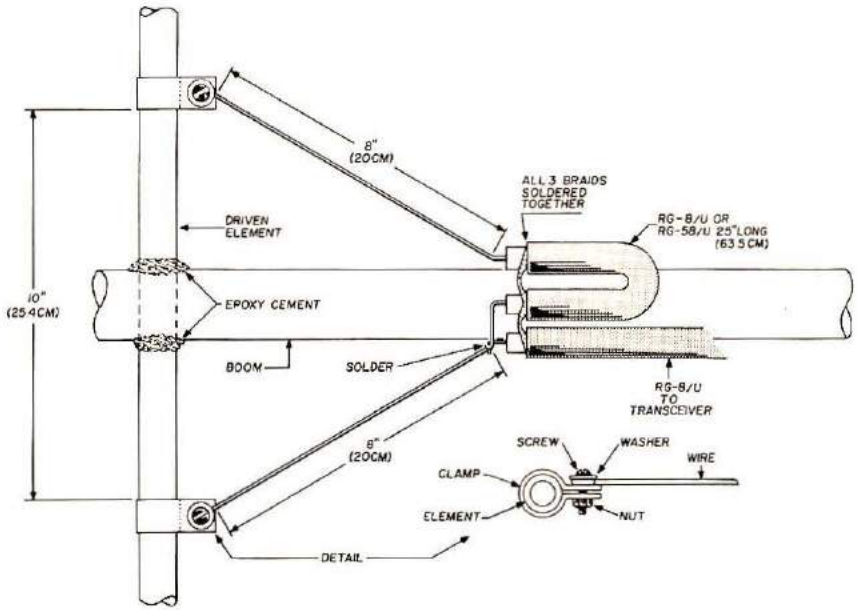
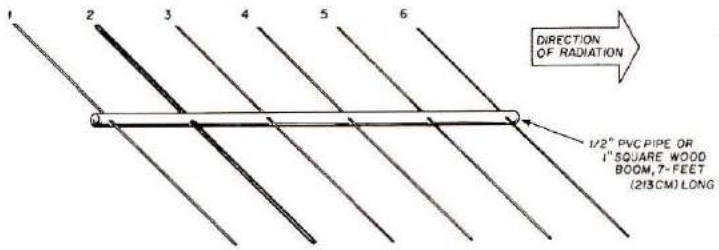



**Fig. 5.** One method of feeding the driven element of a Yagi antenna is called a "delta" match. A 1/2-wave phasing section made of coaxial cable performs the function of changing the unbalanced transmission-line feed into a balanced feed for the antenna element. The dimensions given are approximate, and should not be critical. If you feel that you need to adjust the feed points for minimum reflected energy, always slide both clamps an equal amount, toward or away from the boom, in small steps — 1/8-inch or so. Do not stand near the antenna or place hands near it when taking a reading on an swr meter. The best position for the antenna when making adjustments is pointing straight up, perhaps on top of a wooden stepladder or a similar non-metallic support. The coaxial cable can be taped to the boom, to hold it in place, and the exposed connections should be covered with electrical tape or with GE RTV Silicone sealant. A clear plastic spray to protect the clamps and that portion of the driven element is a good idea.




| ELEMENT | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| LENGTH | INCHES (CM) | 40 (101.6) | 37 3/4 (95.9) | 36 3/4 (93.3) | 36 1/2 (92.7) | 36 1/4 (92.1) | 36 (91.4) |
| SPACING FROM ELEMENT 1 | INCHES (CM) | | 16 (41) | 27 (68) | 43 (109) | 63 (160) | 83 (211) |

**Fig. 4.** A simple Yagi antenna that will provide improved signals either through the Oscar satellites or for medium-distance contacts at ground level. The construction can be very simple — drill holes that are a snug fit for the elements and epoxy cement them in place. The elements can be stiff aluminum rod or small-diameter tubing. The driven element can be 3/8-inch (95mm) diameter tubing. Elements should be 1/8- to 1/4-inch (30 to 60mm) diameter. Element 1 is called a reflector, element 2 is the driven element; 3, 4, 5, and 6 are directors.

*Impedance, in simple terms, is that quality of a circuit or components that impedes the flow of alternating current. Resistance is its counterpart for dc voltage and current. Because ac current and voltage have a phase (time) relationship with each other, simple resistance theory is not accurate enough for engineering purposes. Impedance theory takes all of the ac factors into account; for the very basic antenna theory that we are discussing here, you can think of impedance as similar to resistance.

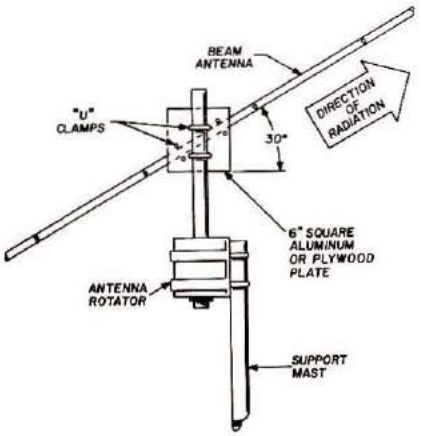



**Fig. 6.** A simple method of using a Yagi antenna for satellite work is to mount it tilted upward at approximately 30 degrees. This will be effective except when the satellite is directly overhead, but that "zone of silence" will not last long.

Now all of this is fine — your half-wave will have a bit more gain than a quarter-wave, and you can match it to the coax in good shape. But, let's take it just a bit further: Make the antenna approximately 5/8-wavelength long. Now, the impedance at the bottom end of it starts to decrease again, and the matching network has less of a chore to perform. It can still be of the same type, either a coil or a tuned circuit, but it has to act as a peacemaker between 50 and 300 ohms, instead of between 50 and 2000. That is not the only benefit either — since it is slightly larger, the 5/8-wave whip has just a teeny bit more gain than a half-wave, and it is quite a noticeable improvement over quarter-wave. A look at **Fig. 7B** will show another characteristic that is most helpful: The angle of radiation is low, which places your signal down where you want it (unless you like to talk to birds or an occasional aircraft).

So, for mobile use, those are the most common, and easy to make, types of antennas. Yes, there are several antennas marketed that have more elements to them, with neat little plastic sections between, and all that. These antennas have more gain than what I just discussed, but as a beginner on fm you can get excellent results with the more simple units.

### Fixed station antennas

Many times you will hear the term "base station" when people are talking about fm and repeaters. This is just a left-over term from the days of commercial two-way radio, when there were two types of units sold on the surplus market: mobile stations and base stations. With a few exceptions, when an Amateur or CBer speaks of a base station, he really is referring to a home-station as compared to the one in his car.

Antennas for fixed-station use can be almost exactly the same as those used for working through satellites, and in fact, many Amateurs do use the same installation for double

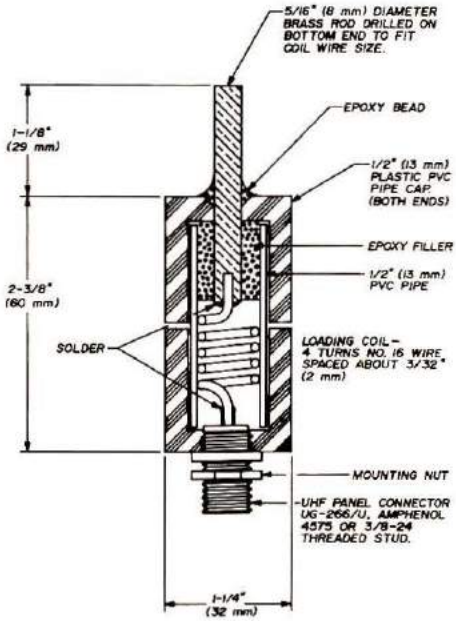

5/16" (8 mm) DIAMETER BRASS ROD DRILLED ON BOTTOM END TO FIT COIL WIRE SIZE.
EPOXY BEAD
1-1/8" (29 mm)
1/2" (13 mm) PLASTIC PVC PIPE CAP (BOTH ENDS)
EPOXY FILLER
1/2" (13 mm) PVC PIPE
2-3/8" (60 mm)
SOLDER
LOADING COIL - 4 TURNS NO. 16 WIRE, SPACED ABOUT 3/32" (2 mm)
MOUNTING NUT
UHF PANEL CONNECTOR UG-266/U, AMPHENOL 4575 OR 3/8-24 THREADED STUD.
1-1/4" (32 mm)

**Fig. 8.** The matching coil for the bottom of a 5/8-wave radiator can be made of wire, mounted inside a few plastic pipe fittings. In the original description of making this type of device, K6KLO used a telescoping whip as the radiating element. Best results were obtained with the whip extended approximately 48 inches. A variety of fittings can be used at the bottom to make connection to the coil, depending upon the need of the builder. From *ham radio*, July, 1974, pages 40-43.

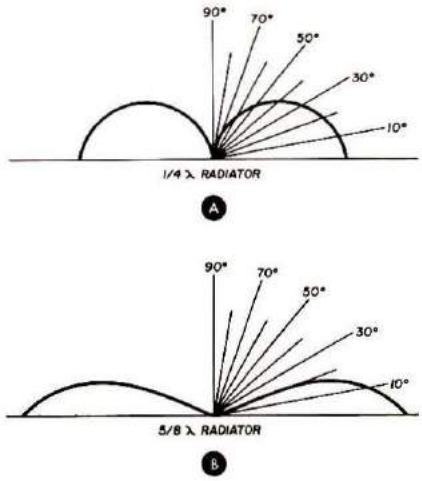



**Fig. 7.** Radiation patterns for vertical antennas mounted above a ground plane such as a metal screen or a flat portion of a car body. The 1/4-wave whip radiates a large part of its energy upward at angles that do little good. The 5/8-wave antenna brings some of that energy down to add to that at low angles, making it more useful at vhf work.

duty. A good Yagi beam will enable you to reach out over the horizon to talk to another fm station, or even to work ssb or CW, if you are lucky enough to own one of the new all-mode transceivers that are now available. (Your antenna doesn't know the difference between a-m, fm, ssb, or CW; it just passes the signal along.) The only caution I'll give you is to be aware of the polarization differences between the various types of stations, and plan accordingly. Most fm stations, mobile or repeaters, use vertical polarization of their antennas. This is mainly because the vertical whip is much easier to handle in a mobile environment, is essentially non-directional, and is not too bad looking (some of the old horizontal attempts at an all-direction mobile antenna were sure attention getters)! Many amateurs solve the polarization problem by using a pair of Yagis — well, it is actually one supporting boom with two sets of elements attached, one vertically and another horizontally. Thus they can select the polarization that they need at the moment by means of a relay, or by doing

some fancy stuff with the coax cable they can feed both at once.

For those of you who would like to stack two Yagis side-by-side, with the elements vertical — yes, that is done too. You do it the same way you would if the elements were horizontal, but just remember to keep the supporting mast near the elements non-metallic. Any nearby metal in the same plane as the elements will distort the pattern and decrease the gain. **Fig. 9** shows one way of making such an array.

While I am talking about stacking antennas let me point out that there is an easy way to estimate the gain improvement when you stack identical antennas: Each time you double the size of the array you increase the gain by 3 dB, theoretically. I add that modifier because there is a small amount of power lost through the feedline harness that you need to combine the two antennas, and the spacing between them must be just right, too. A good rule of thumb is that the spacing should be 1/2 wavelength, or half the boom length, whichever is greater.

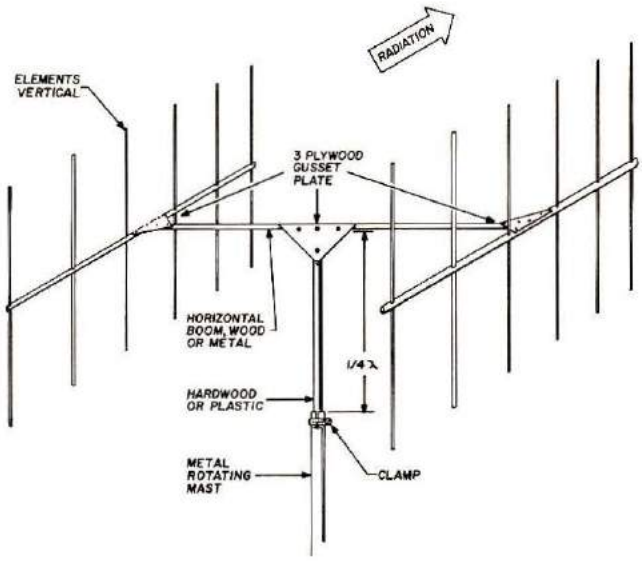



**Fig. 9.** The use of Yagi antennas to help in working distant fm stations requires that the elements be in a vertical plane. A vertical support, if of metal, would distort the antenna pattern and decrease the effectiveness of the array. You can make the top 1/4 wavelength of the support of hardwood (treated for weather-proofing) or of tough plastic, and avoid the distortion problem. If two Yagis like that shown in **Fig. 4** are used, they should be spaced 42 inches (106cm) apart.

I have been talking mostly about antennas for the 144-MHz band, but everything I've said pertains to all the vhf bands as well. For those of you who would like to experiment with antennas, **Table 1** provides a list of some important dimensions you can use. There are many excellent antenna books and manuals available (see **Bibliography**), and there is a certain amount of satisfaction in being able to turn a few pieces of wire and tubing into something that will help your signal get way, way, out.

For those of you who are not

**Table 1.** Some useful dimensions for vhf antennas and transmission lines.

| | 50 MHz | | 146 MHz | | 222 MHz | | 432 MHz | |
|---|---|---|---|---|---|---|---|---|
| Frequency | Inches | (cm) | Inches | (cm) | Inches | (cm) | Inches | (cm) |
| 1 wavelength [1] | 236.2 | (600) | 80.8 | (205.2) | 53.2 | (135.1) | 27.3 | (69.4) |
| 5/8 wavelength | 147.6 | (375) | 50.5 | (128.4) | 33.2 | ( 84.4) | 17.1 | (43.4) |
| 1/2 wavelength | 118.1 | (300) | 40.4 | (102.7) | 26.6 | ( 67.5) | 13.7 | (34.7) |
| 3/8 wavelength | 88.6 | (225) | 30.3 | ( 77.0) | 19.9 | ( 50.6) | 10.2 | (26.0) |
| 1/4 wavelength | 59.0 | (150) | 20.2 | ( 51.3) | 13.3 | ( 33.7) | 6.8 | (17.3) |
| 1/2 wavelength coax [2] | 77.9 | (198) | 26.6 | ( 67.7) | 17.5 | ( 44.6) | 9.0 | (22.9) |
| 1/4 wavelength coax [2] | 38.9 | ( 99) | 13.3 | ( 33.8) | 8.7 | ( 22.1) | 4.5 | (11.4) |
| 1/2 wavelength twinlead [3] | 96.8 | (246) | 33.1 | ( 84.1) | 21.8 | ( 55.4) | 11.2 | (28.4) |
| 1/4 wavelength twinlead [3] | 48.3 | (123) | 16.5 | ( 40.0) | 10.9 | ( 27.7) | 5.6 | (14.2) |
| Per cent change each MHz [4] | 2 | | 0.6 | | 0.45 | | 0.25 | |

**Notes:** (1) Dimensions are based on the wavelength-in-air formula 11810/F(MHz).

(2) Coaxial-cable lengths are based on the velocity factor of RG-8/U or RG-58/U, which is approximately 0.66.

(3) Twinlead lengths are based on the velocity factor of 0.82 for common TV lead-in of parallel wires with flat, solid-dielectric insulation.

(4) The dimensions given are for frequencies in the most-often used part of the bands. The dimensions *increase* as you go lower, and *decrease* as you go higher in frequency. Example: If you want to work at 51 MHz, decrease the dimensions given by 2 per cent; for 145 MHz, increase the dimensions by 0.6 per cent.

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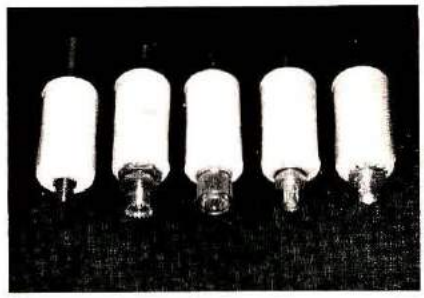

Five types of fitting for the bottom of the assembly are shown here. At the left is one with a threaded stud, for mounting on an insulating base. Next is a UHF female fitting, a UHF male, then two types of BNC connector. In the threaded-stud type, the bottom of the coil connects to the stud, and the center conductor of the coaxial feedline should fasten to this same stud after it has been passed through the insulating mount. In all of the coaxial-fitting type of mounts, the coil connects to the center conductor inside the assembly, and the coaxial feedline connects in the normal manner through its fitting. See **Fig. 8.**

inclined, or don't have the time, to experiment and build your own, I hope the discussion and drawings will give you some ideas of what to shop for to get the performance you want at your station for Oscar, repeaters, mobile, or DX work.

Now, go get that General or Technican class license and join the fun!

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**HRH**